
External Design of Relays

4.1 Environmental Impact on Relays

In practical service conditions, relays are affected by negative environmental factors, which can considerably change their characteristics. Changes in the temperature of the environment may cause changes in the linear dimension of a core, an armature, a case, and other significant elements of a relay. As a result, distortion of movable parts and even jamming may occur. Changes in the resistance of relay windings and the modulus of elasticity of a restorable spring can lead to considerable changes in relay pickup (operate) and dropout (release).

As the temperature increases from $+20$ to $+100^{\circ}$, the insulation resistance of a relay decreases practically by ten times. Strange as it might seem, even increased air humidity can lead to changes in pickup and release currents of a relay. Oxide films and corrosion in joints of the movable parts of a relay may cause pickup current multiplication of 10 to 15%. Temperature fluctuations varying from 0 to -20 – 60° may result in malfunctions of a relay caused by freezing of contacts. As air-pressure goes down, its electric strength considerably decreases, in accordance with Paschen's curve (Figure 4.1). As it can be seen from the curve, minimum electric air strength is about 320 V/mm at a pressure of 4 to 5 mm Hg, corresponding to 42 km height. This fact must be taken into account for relays designed for aircraft and rockets.

When relays are used in movable units or stationary equipment affected by vibration, they are prone to external mechanical vibration loads of different frequencies and amplitude. Under vibration the pickup current of a relay usually decreases by 5 to 25% because of recurrent reduction of the magnetic circuit gap, easier relay operation at the moment, and also because of a decrease in the constant of friction between movable and stationary elements. In addition, the pressing strength of the closed contacts may also change occasionally. A weakening of this effort may lead to contact welding. If this frequency of external oscillations is in accordance with the frequency of natural oscillations, resonance may occur, causing a sharp increase in the amplitude of oscillations, bringing about opening of closed contacts or closing of open contacts, breaking winding outlets, and eventually causing mechanical collapse of the relay. Relay specifications usually indicate frequency band and amplitude (acceleration) range, at which no spontaneous closing or opening of the contacts will occur, and at which the pressing effort (strength) remains great enough for a continuation of reliable work.

Apart from vibration, a relay installed on movable units is also prone to linear acceleration. Most relays are affected by strong acceleration during aircraft take-off, in-flight maneuvers of military aircraft, and missile take-off. In these cases if special precautions are not taken, relays may be picked-up spontaneously. Relay with so-called "balanced

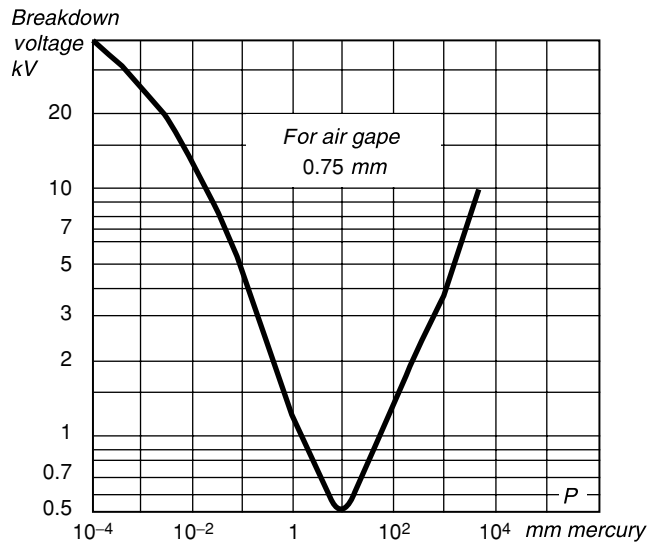


FIGURE 4.1
Paschen's curves for air.

armature" (see above) have the highest resistance to linear accelerations. This type of relay is the most widespread today. Some years ago in some cases relays with an attracted-armature magnetic system (see [Section 2.3.1](#)) were used in operations with linear accelerations. Such relays were designed in such a way that spontaneous energizing in the direction of acceleration could be avoided.

Relays are also very sensitive to current-conducting dust or gases causing metallic corrosion. For example, unprotected relays installed in automation systems of big poultry-yards or stock farms will go out of action quickly due to the corrosive impact of ammonia.

4.2 Wood and Cardboard: First Protection Shield For Relays

Of course the necessity of relay protection was not realized at once. It took decades to form a system of knowledge about negative impacts on relays and means of protection. However, due to intuitive realization of the fact that relays are sensitive and precision devices that can be easily damaged, the first relays were also supplied with some elements of protection.

At first, these were simple frames ([Figure 4.2](#)), and then later wooden boxes ([Figure 4.3](#)). Simple cardboard boxes were used as shipping containers ([Figure 4.4](#)). Wooden boxes for relays had been used for a long time (at that time wooden constructions were widely used in engineering). For example, in the 1935 directory of the biggest English electrotechnical company, General Electric Co. (later GEC Measurements, now Alstom), there are quite a lot of relays in wooden cases for different purposes ([Figure 4.5](#)).

By the end of the 19th century, some companies began producing relays in round metal cases with wooden heelpieces ([Figure 4.6](#)), supplied with convenient clamps for switching of external circuits. Later on, durable metallic cases were also widely used for other types of relays, in particular for relays used in military equipment ([Figure 4.7](#)).

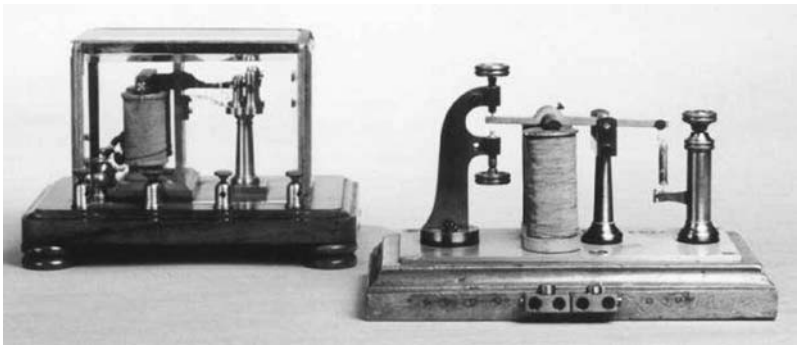


FIGURE 4.2
First half-covered relay (on the left).

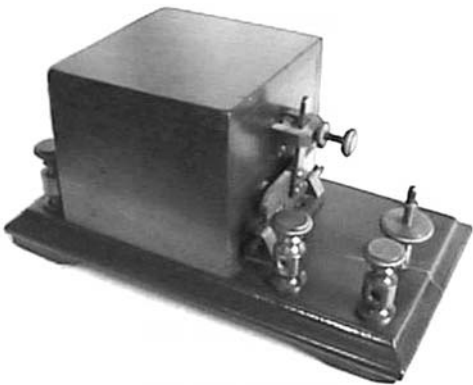


FIGURE 4.3
One of the first covered relays.

As production of plastic became widespread in the middle of the 20th century, protection shields for relays gained their modern design (Figure 4.8). According to the modern classification there are open relays and dust-proof and sealed relays. Due to the quite strong environmental impact on relays, open relays are very rarely used now. In constructions of the second type, either plastic cases snapping shut at the heelpiece of the relay, or expanded aluminum cases, are most often used (Figure 4.9). There are a few types of plastic cases (Figure 4.10 and Figure 4.11), that provide different levels of protection.

To protect the winding from mechanical damage and humidity it is often impregnated with epoxide resin.

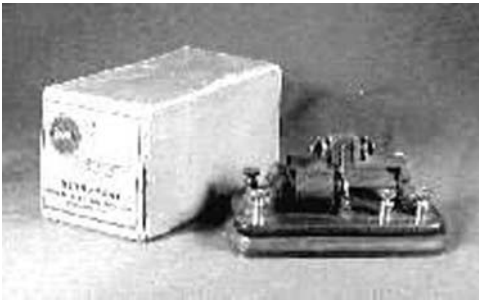


FIGURE 4.4
Cases for packing of early relays.

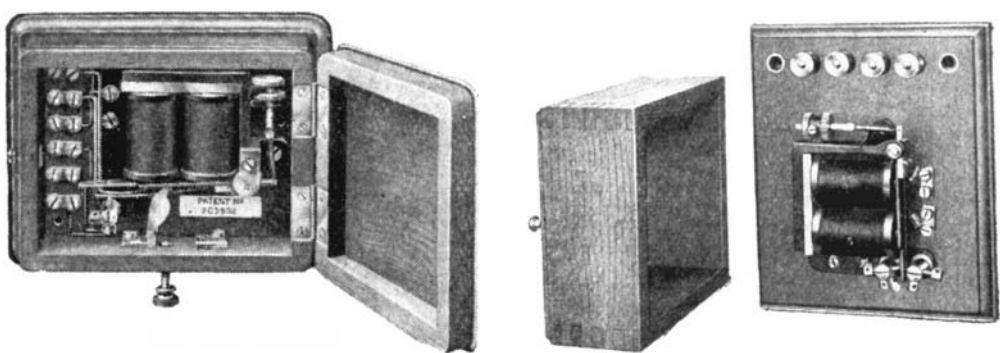


FIGURE 4.5
Relays for automation systems in wooden cases produced by General Electric Co. (From the G.E.C. Catalog of Electrical Installation material, 1935.)

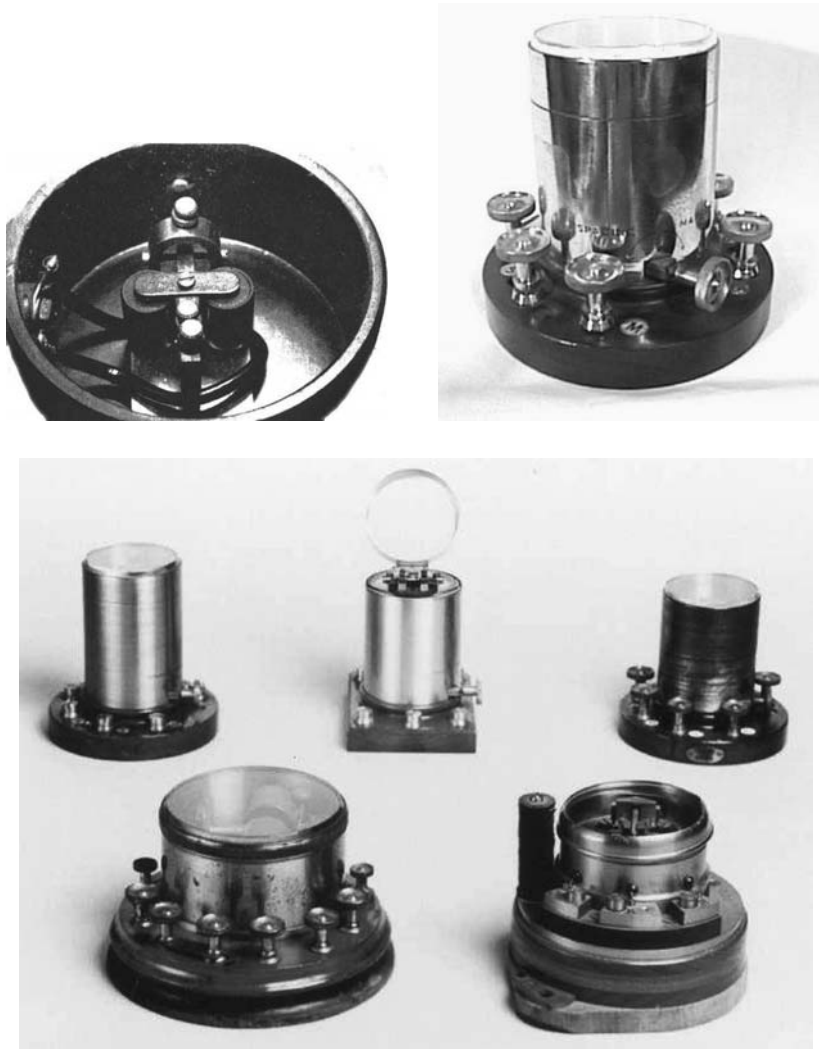


FIGURE 4.6
Telegraph relays of the 19th century in round metal cases.

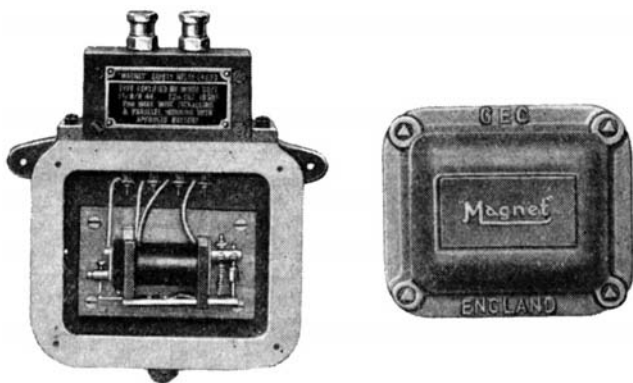


FIGURE 4.7
Relay in heavy metallic case for military equipment produced by General Electric Co. on request of the Mine Department in the 1930s. (From the G.E.C. Catalog of Electrical Installation material, 1935.)

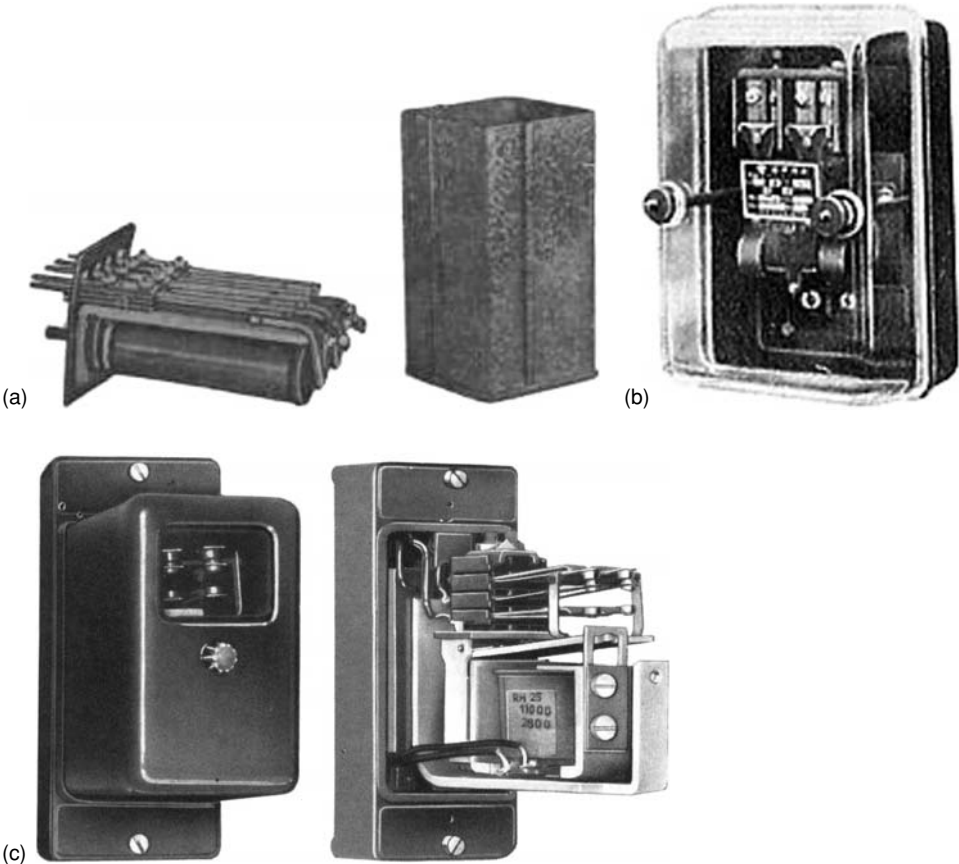


FIGURE 4.8
Relays with plastic protection shields produced in the middle of the 20th century. (a) Ericson relay; (b) Omron relay; (c) Siemens relay of RH-25 type (Russian relay of MKU-48 type has a similar design).

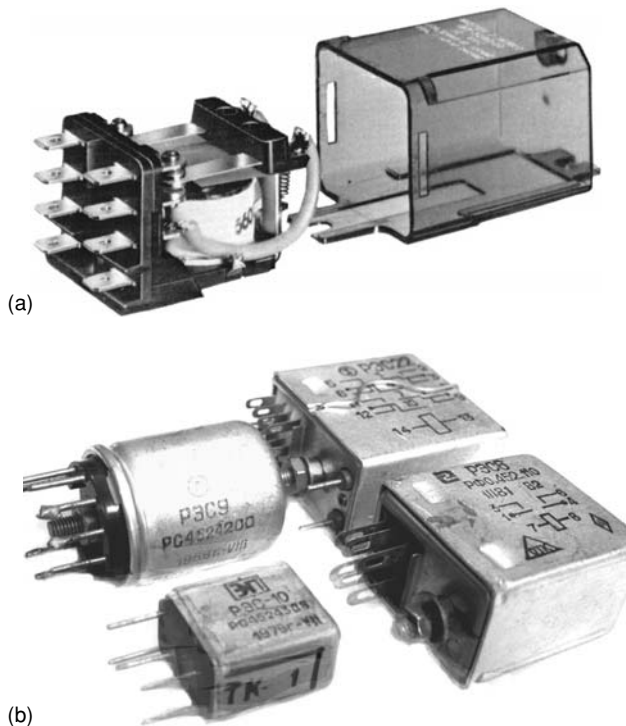


FIGURE 4.9
Modern dust-proof relays in (a) plastic
and (b) aluminum cases.

4.3 Is a Sealed Relay Always Better than an Open One?

On the face of it, all dust-proof relays may seem to be less prone to environmental impact than open ones, but paradoxical as it might seem this is not true.

At increased humidity of the environment, moisture gradually penetrates the relay through the uptight joint of the heelpiece and protective case, and remains for a long period of time because of the lack of ventilation. Also, when there are fluctuations of temperature and air-pressure, humid air may be sucked into the relay. After switching ON and warming of winding, moisture may be condensed on contacts and can sometimes lead to water bridges between the opening contacts. Moisture, together with the difference of potential on the contacts, may cause more intensive processes of decomposition of the contact material. Long-term moisture leads to a sharp decrease in insulation resistance and a further lowering of temperatures — even to icing over of contacts and windings.

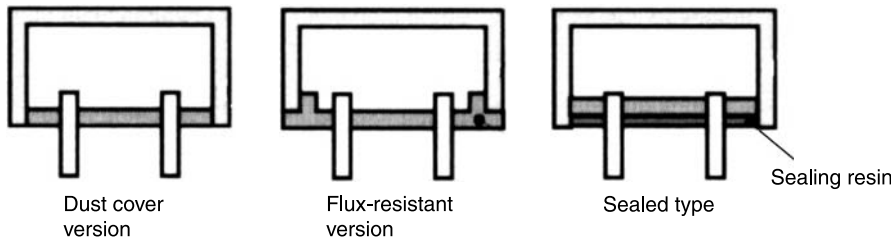


FIGURE 4.10
Schemes of plastic cases of different types.

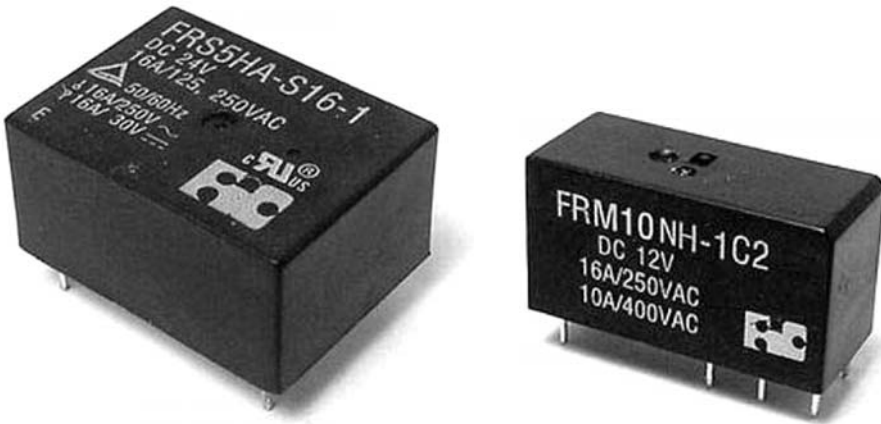


FIGURE 4.11
Relays in plastic cases sealed by epoxide resin (sealed-type relays).

For these reasons dust-proof relays are frequently more prone to high humidity impact than open ones; nevertheless, such relays are still better protected from dust and external mechanical effects.

To enhance reliability of dust-proof relays under high humidity conditions, some models are produced with vent doors in cases of approximately 1 cm² in area, covered on the inside with a few layers of poultry netting (8 to 10 thousand of meshes per square centimeter). Such netting protects the relay against dust, but allows air circulation inside the relay.

Sealed relays with welded metal cases have a more perfect design allowing protection of all internal elements of the relay from environmental impact (Figure 4.12). However, special materials and technologies are required to produce them mostly, because even small amounts of substances which usually do not affect open relay operation can have a strong negative impact if found in small stoppered cases of sealed relays. As metal vapors or flux arise during soldering or welding of contacts, or sealing of the case, such substances

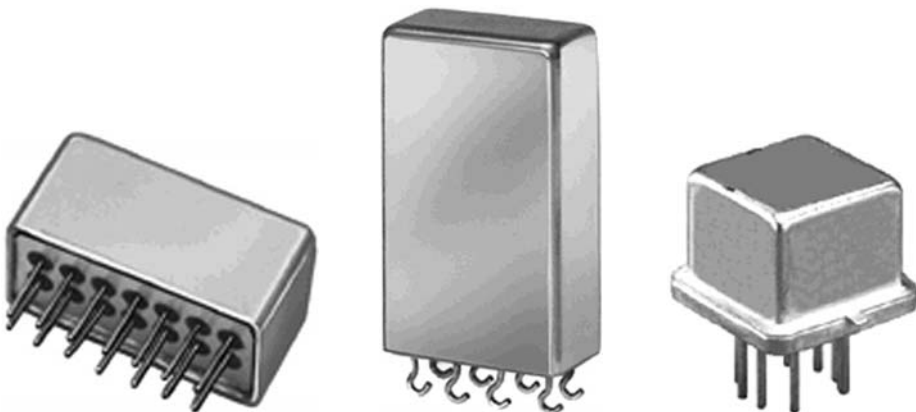


FIGURE 4.12
Relays sealed into metal cases.

can penetrate or pass under the relay shell as it is being produced. Hazardous substances can also be released in the course of relay operation when elements such as plastic coil bobbin or enameled wire are heated, because of which special materials are required for sealed relays, and production must be carried out in absolute cleanliness. This is similar to the process required for production of vacuum electronic devices. In some cases, double sealing is required to avoid gas contamination from the winding: the winding is hermetically insulated from the contact system inside an external sealed case. Before sealing-in, the relay is degassed in a vacuum thermostat under pressure of not more than 10^{-4} mm Hg and a temperature of about 170 °C, and is filled with a dehydrated mixture of nitrogen (90%) and helium (10%). Vacuum-tight sealing of relay outlets is carried out by lead-out pins made from Kovar[®] (Kovar[®] is a registered trademark of Carpenter Technology Corporation). Kovar alloy is a vacuum melted, iron–nickel–cobalt low expansion alloy whose chemical composition is controlled within narrow limits to assure precise uniform thermal expansion properties. Outlets, insulated with glass insulators, soldered inside relay with argon-arc welding or in a hydrogen environment (Figure 4.13).

You may think that such relays are perfectly protected against moisture and Paschen's curves, but in fact it is not so. Of course there will be no more problems with internal elements, but how are we to deal with external elements such as outlets, for example?

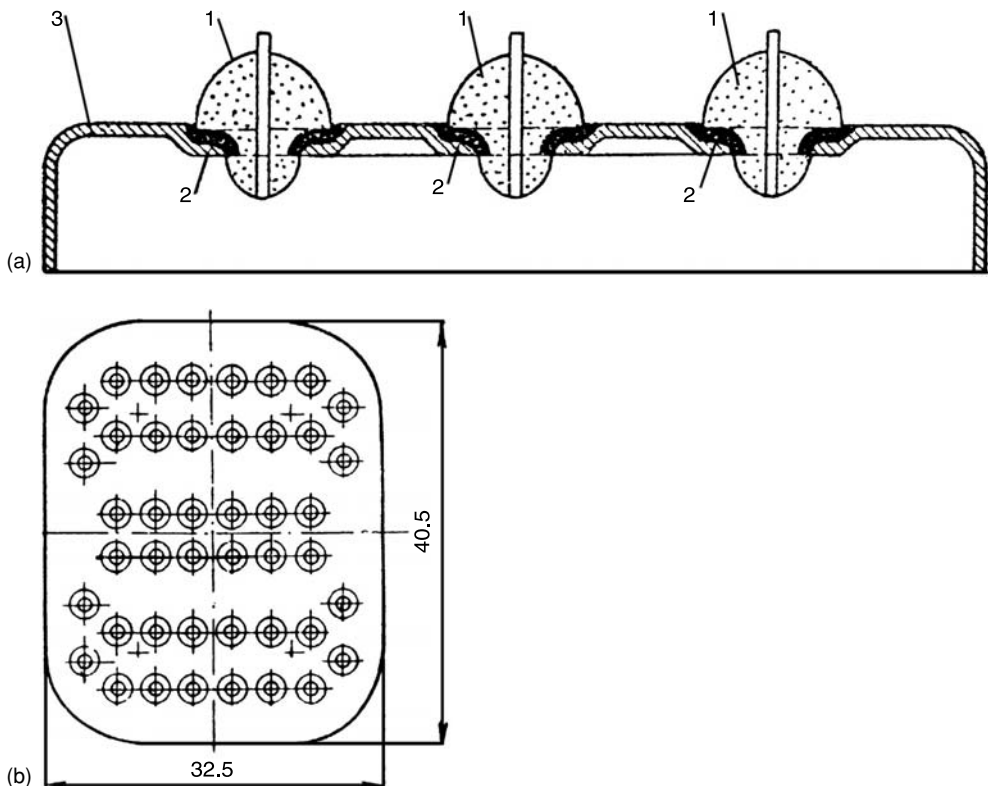


FIGURE 4.13

(a) Sealed relay outlets. 1 — glass insulators, 2 — layer of silver baking into glass; 3 — metal heelpiece. (b) Heelpiece of a DP-12 relay with 12 switching contact groups.

4.4 Outlets, Terminal Sockets and “Containers” for Relays

Multi-contact relays have a number of such elements (Figure 4.14). Since the heelpiece area is quite small, glass insulators are also very small in size (about 3 mm in diameter with about 1 mm of surface leakage path).

Here problems begin to arise. If under normal air-pressure such glass insulators can withstand AC voltage with an active value of more than 2000 V (which is more than enough for miniature sealed relays), at 15 km height (when air-pressure is about 70 mm Hg) breaking-down voltage reduces to 700 V and at 42 km height already to 200 V. Moreover, at working voltage subnormal discharge may arise between the contacts.

External contamination of a relay with dust, and increased humidity may lead to an increase in leakage current on the glass insulator surface, even under normal air-pressure. So safe protection of just the internal elements is not enough for reliable relay operation. It is also essential to protect the outlets. Usually such protection is carried out in the equipment itself after the relay has been installed. In case of point-to-point wiring, the heelpiece of the relay is covered with foamed sealant or silicon. If a relay is installed on a printed circuit board, the whole board and the relay together are covered with several layers of high quality waterproof varnish.

Modern relays can have outlets of different types. Sealed relays have direct outlets for soldering into a printed circuit board or hooks for point-to-point wiring (Figure 4.14). As has been mentioned above, outlets of sealed relays are made of a special alloy called Kovar in order to obtain a coefficient of expansion similar to that of glass, but this material is not the best conductor of electric current, which is why the outlets are sometimes made bimetallic to increase their carrying capacity with the internal copper core pressed into an external tube made of Kovar.

The diversity of outlets for industrial relays is even greater. It used to be quite easy to install such relays in equipment (in control cabinets, for instance) when they were large in size and had their own terminal sockets for connection of external wire (Figure 4.15). The solution was to provide small relays with pin-like (or flat) outlets (Figure 4.16). They were designed to be inserted into terminal sockets (Figure 4.17), and supplied with screw clamps for connection of external wire. Many of them look like sockets of old radio valves and similar size spectrum — heelpiece with eight-pinned radio valves (Figure 4.17) — used for relay outlets. Such terminal sockets can be called an interface-providing joint of

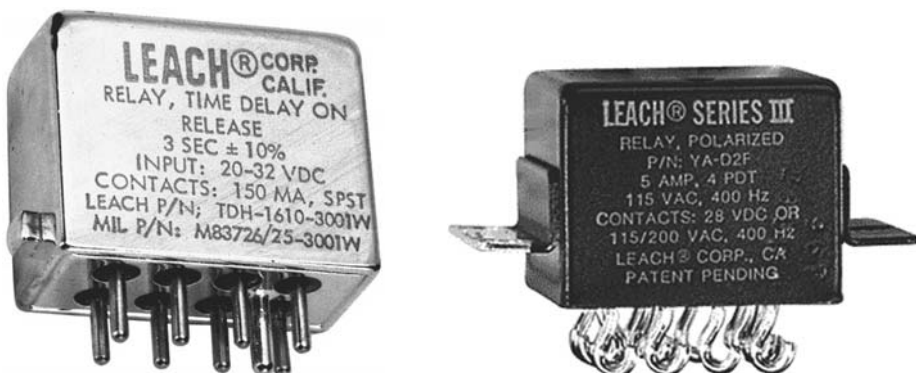
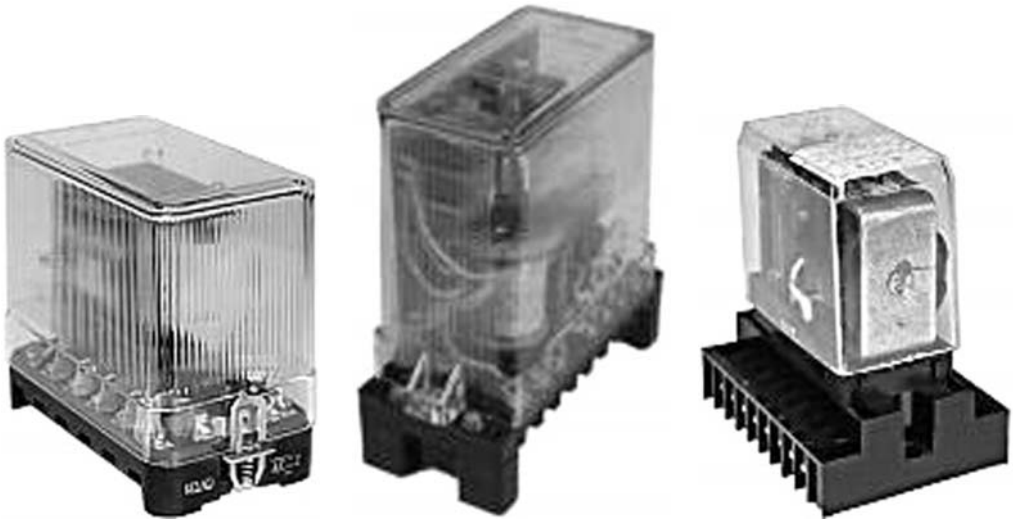
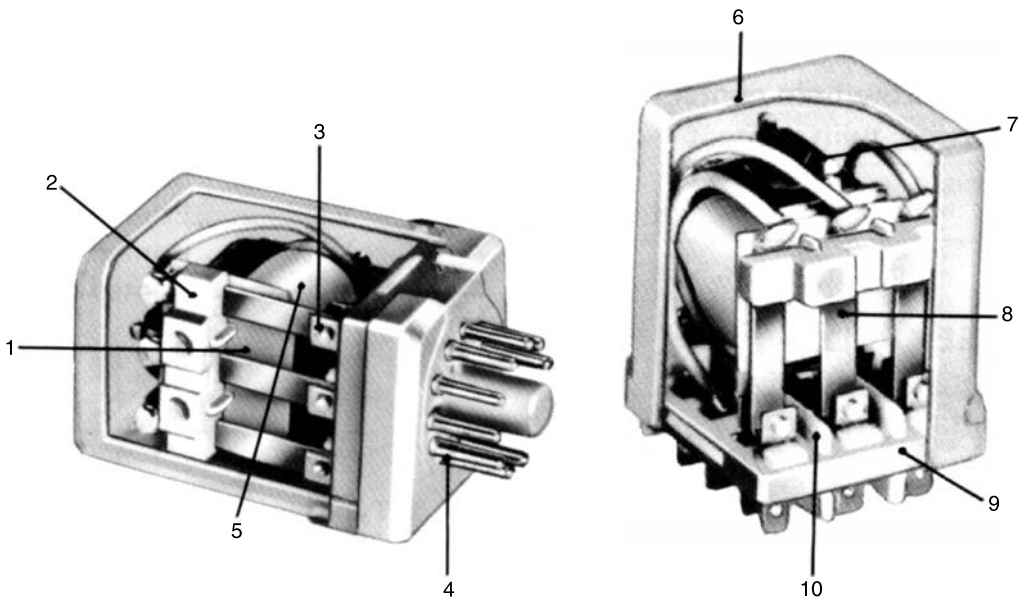


FIGURE 4.14
Various types of outlets of sealed relays.

**FIGURE 4.15**

A large industrial relays with its own sockets, with screw clamps for connection of external wire.

small relays to external circuits. These sockets may be two and even three-steps in height, thus saving space in the cabinet if the relay has many contacts. Due to such terminal sockets relays can be assembled and dismantled easily, quickly, and conveniently (Figure 4.18), and sockets can be also easily installed on a standard DIN Rail (Figure 4.19). Due to a great number of spring-loaded pins in a terminal socket a relay

**FIGURE 4.16**

Industrial relay with pin-like outlets (terminals). 1 — insulation sheet; 2 — movable contact; 3 — fixed contact; 4 — terminals; 5 — coil; 6 — transparent dust-proof case; 7 — releasing spring; 8 — movable contact spring; 9 — base; 10 — insulating barrier.

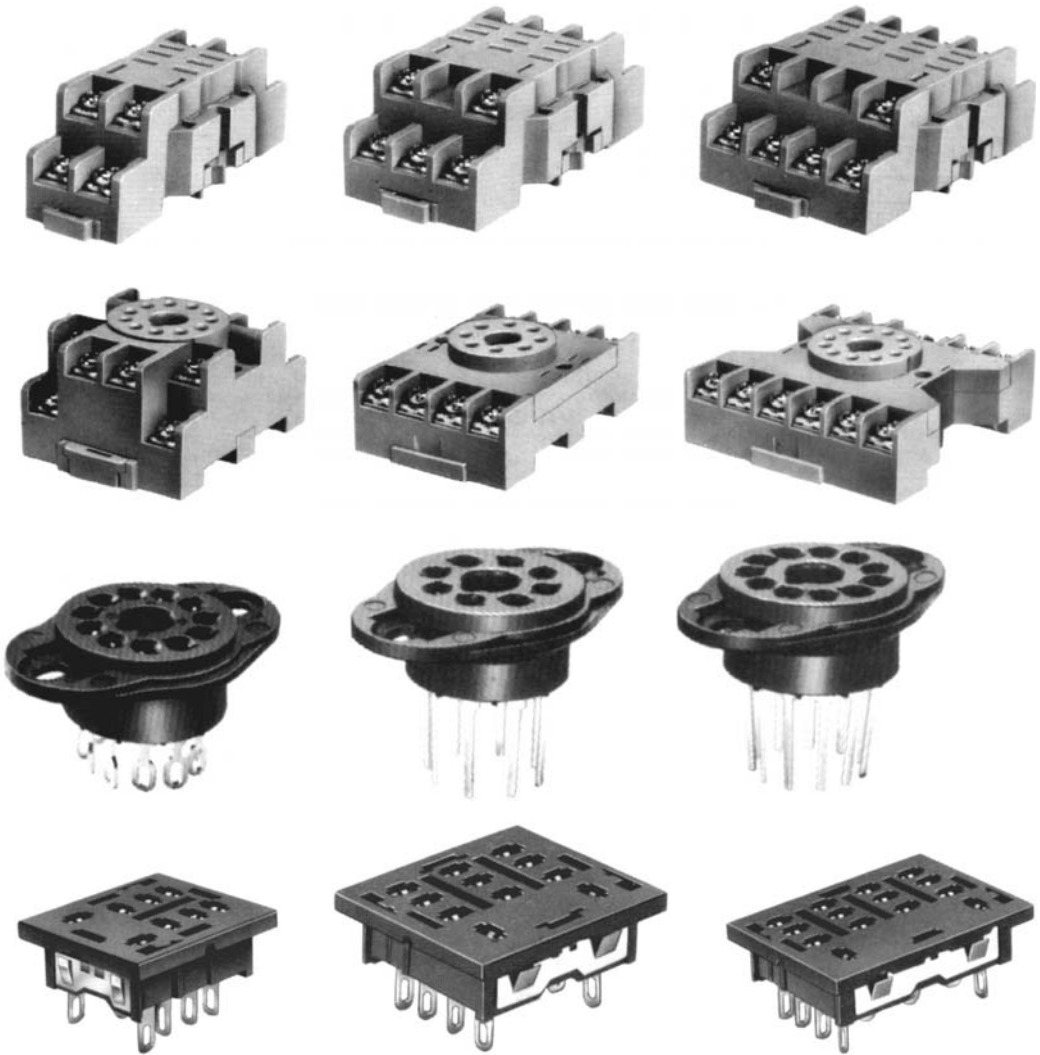


FIGURE 4.17
Terminal sockets for industrial relays.

is well held in a vertical and horizontal position, however, it is not recommended to install relays vertically downwards on such terminal sockets, because long-term vibration can cause the falling out of a relay from a terminal socket.

Many firms produce terminal sockets supplied with a special lock holding a relay in any position in space (Figure 4.20). Sockets of this type allow assembly of relays in electric cabinets with very dense mountings, with the help of a DIN Rail.

The designers of Phoenix Contact created a whole world of original constructions based on the use of terminal sockets holding relays on standard DIN Rails in electric cabinets (Figure 4.21). In particular they designed original “containers” where ready-for-service relays produced by other firms were placed (Figure 4.22). Pin-like outlets of a container allow direct installation of relays on standard terminal-socket connectors used for connections of wire in electric cabinets.

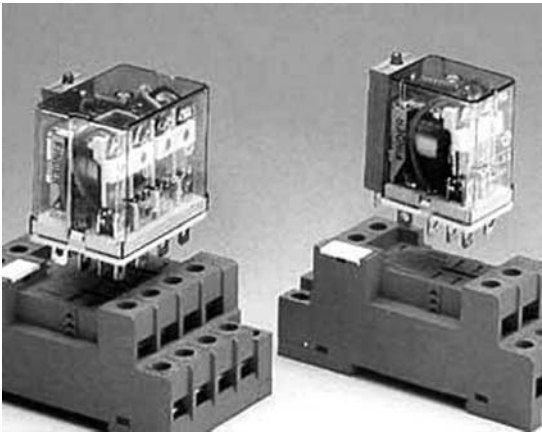


FIGURE 4.18
Installation of a relay on terminal sockets.

The Phoenix Contact Company uses some other original principles of positioning of a relay on standard DIN Rail ([Figure 4.23](#)).

Despite the modern tendency to produce miniature relays, some companies still manufacture equipment exceeding modern industrial miniature relays in size. Such equipment is similar (by size, by contact, and by magnetic systems) to relays produced at the beginning of the 20th century. World leaders in the electric-power industry, such as concern ABB, produce such relays, designed for use in electrical power systems.

Production of such large electromagnetic relays is connected with a tendency to unify sizes for protective relays used in the electric-power industry. Protective relays are complex devices containing elaborate magnetic and electronic systems and are quite large in size. Perhaps large electromagnetic relays are better arranged with protective relays in relay protection cabinets, however, in some industrial automation systems there are so many auxiliary relays that several cabinets are required to install and to mount them all ([Figure 4.24](#)). In this case it is the consumer who is to pay with his working areas for producers' adherence to their own standards.

Of course such relays do have modern designs ([Figure 4.25](#)) and features such as original construction of outlets. By external design as well as by construction, it appears to be a multi-contact connector ([Figure 4.26](#)).

The General Electric Company has been producing protective relays in big and heavy metal cases with detachable glass doors for many years. For example, differential relays of PVD, BDD type or others, have size of $380 \times 168 \times 160\text{mm}$ and a weight of 8 to 10 kg

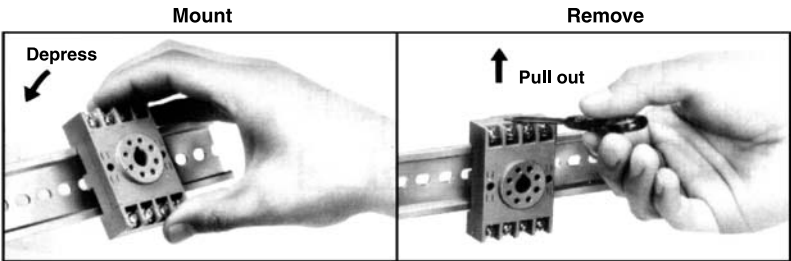


FIGURE 4.19
Installation of a terminal socket on a standard DIN Rail.

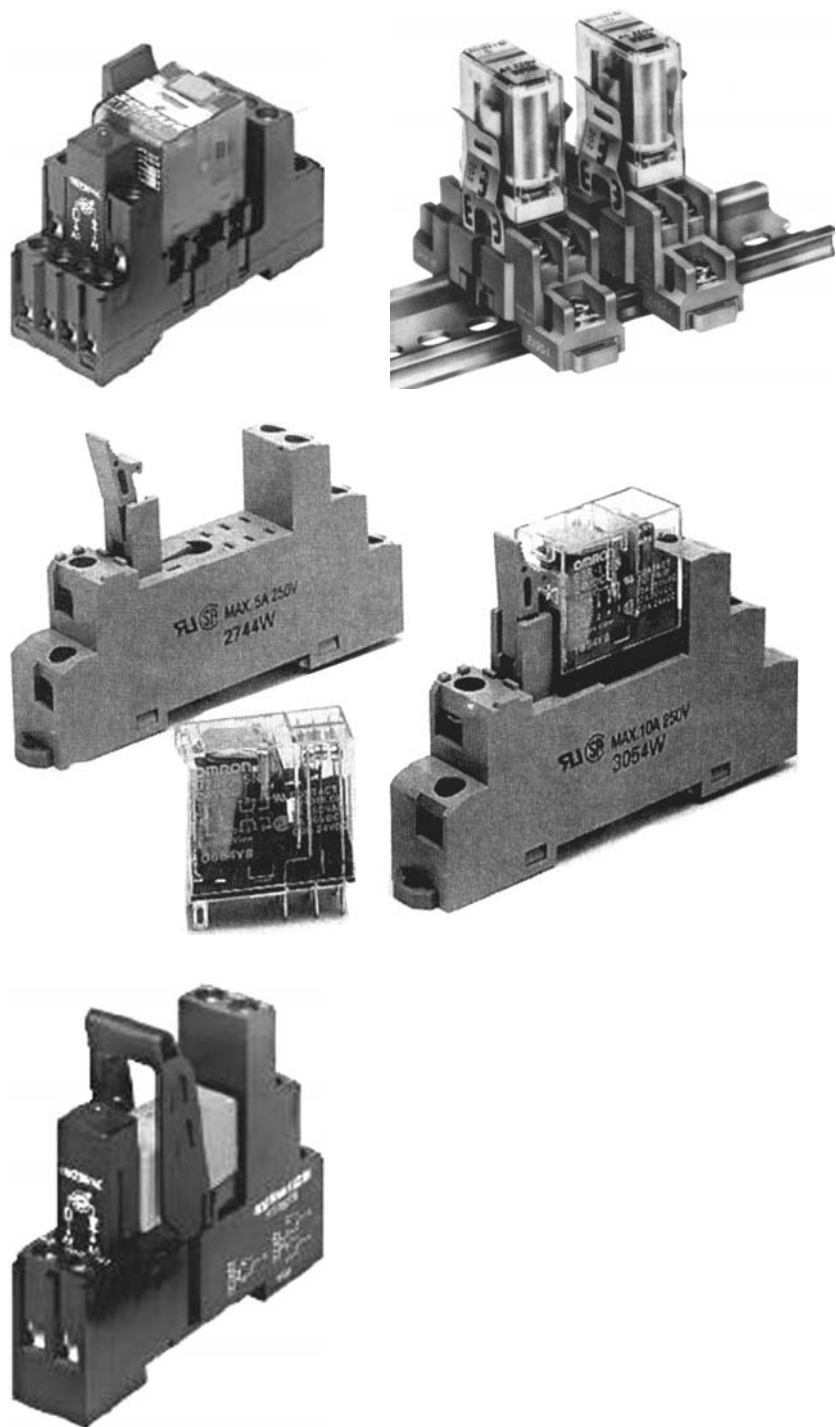
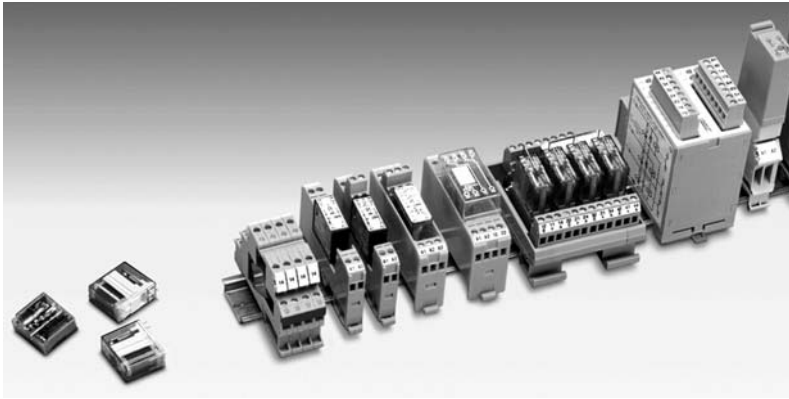


FIGURE 4.20
Rail mount terminal sockets are supplied with a special lock (produced by Omron, Shcrack, Idec).

**FIGURE 4.21**

Terminal sockets produced by Phoenix Contact GmbH & Co KG for mounting of different types of relays on standard rails in electric cabinets. (Picture Courtesy Phoenix Contact GmbH & Co., 2004.)

(Figure 4.27). In spite of the fact that modern relays contain electric and microprocessor-based systems, cases remain the same. This probably happens because such cases are popular around the world since they provide safe protection of the relays against external stress, dust, and magnetic fields. Special plug-in connectors (plug-ins) can be attached to them, allowing connection of external devices to test the relay without having to dismantle it from the circuit. Simple electromagnetic relays have also been produced in similar standard cases (Figure 4.28).

According to different types of mountings (Figure 4.29), modern industrial miniature relays may have different outlets (Figure 4.30). It is obvious that small low-power relays designed for installation on a printed circuit board will have relatively thin straight (or curved, for surface mounting) outlets placed at a standard distance to each other. More powerful relays are supplied with larger outlets designed for soldering of external wire, insertion of them into a terminal socket, or switching of the conductors with the help of a special connector, the so-called “faston” (Figure 4.31).

How are we to deal with a power relay that is to be installed on a printed circuit board?

For this purpose firms have designed and constructed relays with TMP-type outlets containing both thin straight outlets of winding for printed circuit wiring (below) and powerful contact outlets for switching massive external conductors with the help of fastons (above — Figure 4.32).

More powerful relays are supplied with screw clamps for external connection of massive wire. As a rule, in order to save space needed for mounting of the relay these clamps are placed on the top of the relay case (Figure 4.33). There is a connection between modern tendencies of development of electromagnetic relays with an increase of switching capacities, on the one hand, and with the process of micro-miniaturization on the other hand (Figure 4.34).

It took many engineering efforts to develop constructions of cases, fastening elements and outlets, but for micro-miniature relays — a masterpiece of engineering — designers did not have to reinvent these elements: micro-miniature relays were placed into standard cases of transistors or chips (Figure 4.34), which were simply soldered into a printed circuit board without any additional fastening elements.

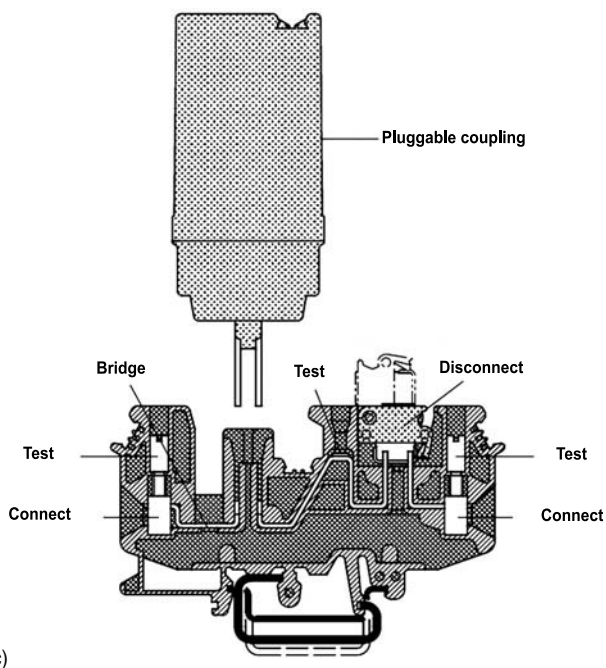
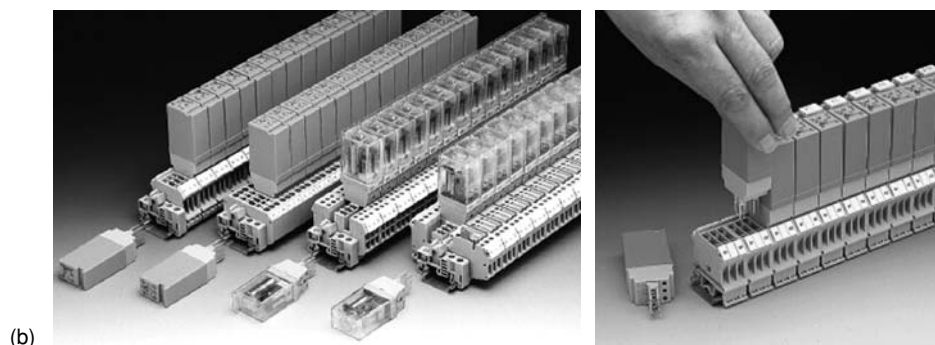
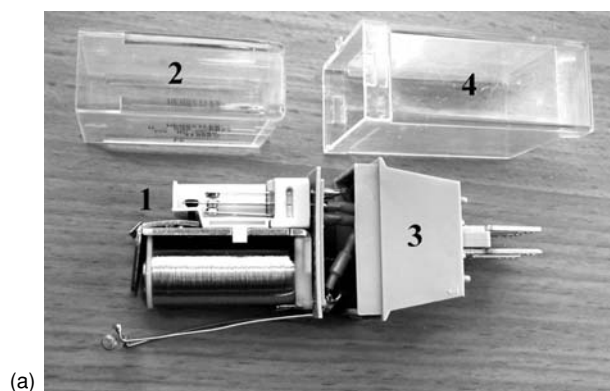


FIGURE 4.22

(a) Construction of a container with a relay installed inside. Produced by Phoenix Contact GmbH & Co KG. 1 — ready-assembled electric relay; 2 — plastic case of the relay; 3 — container with pin-like outlets produced by Phoenix Contact; 4 — plastic case of the container. (b) Installation of containers with electromagnetic relays on mounting terminal sockets (Phoenix Contact). (c) Construction of a cell of a mounting terminal socket produced by Phoenix Contact. (Picture Courtesy Phoenix Contact GmbH & Co., 2005.)

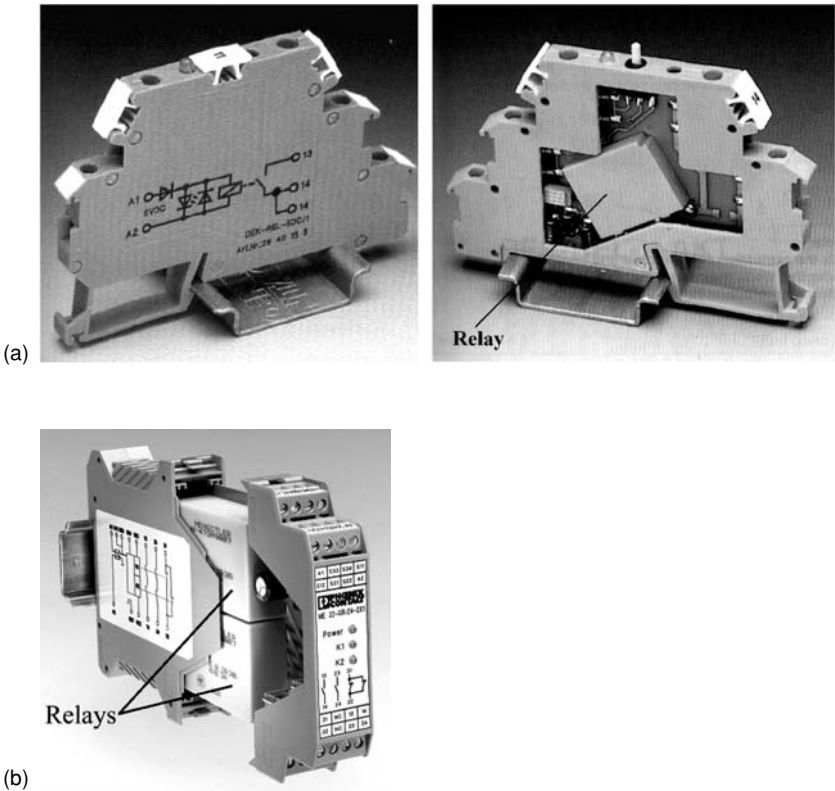


FIGURE 4.23

(a) Mounting of a ready-assembled miniature relay supplied with a plastic case on a standard DIN Rail (Phoenix Contact). (b) Another method of mounting an industrial relay in a special collapsible plastic case designed for installation on a standard DIN Rail (Picture Courtesy Phoenix Contact GmbH & Co., 2006.)

FIGURE 4.24

Cabinets with auxiliary electromagnetic relays, produced by ABB, installed in one of the industrial enterprises.



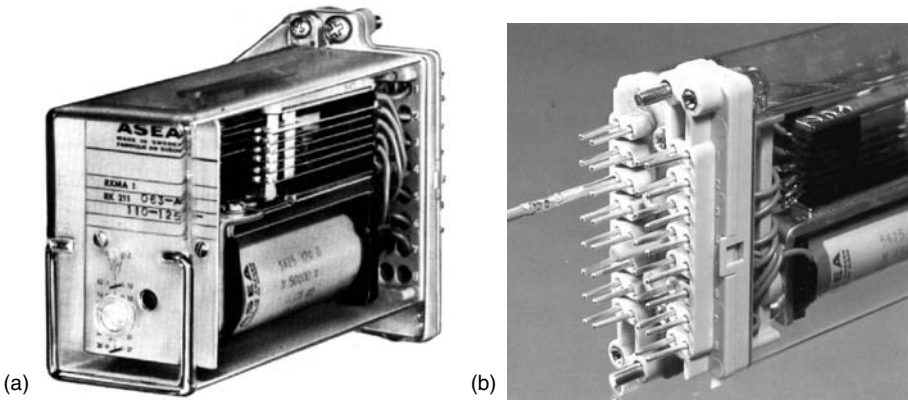


FIGURE 4.25
(a) Modern electro-magnetic relay of RXMA-1 type used in cabinets of relay protection as an auxiliary relay (produced by ABB). (b) Terminal socket of RXMA-1 relay. (From ASEA Relays, Buyers Guide B03-00011E.)

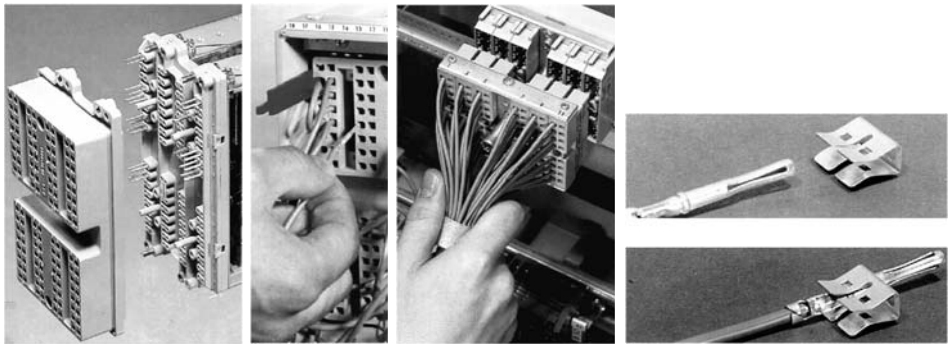


FIGURE 4.26
Peculiarities of mounting and elements of construction of a relay socket produced by ABB. (From ASEA Relays, Buyers Guide B03-00011E.)



FIGURE 4.27
Relays of differential protection produced by General Electric

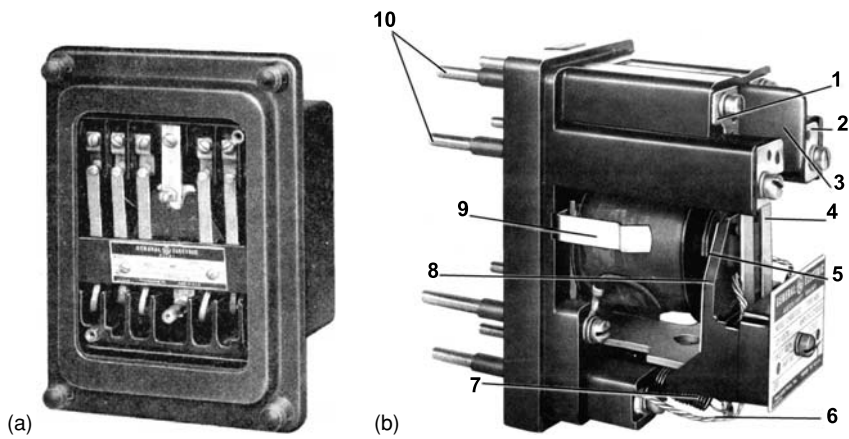


FIGURE 4.28
Electromagnetic auxiliary relays produced by General Electric: (a) — a multi-contact relay in a standard case. (b)— a relay with two switching contacts extracted from a case; 1 — normally open contact; 2 — normally closed contact; 3 — voltage barrier; 4 — spring leaves for moving contacts; 5 — pole piece; 6 — flexible lead; 7 — control spring; 8 — hinged armature; 9 — cover spring clip; 10 — connection studs. (From GE. catalog With permission.)

Insertion mount	Surface mount	Socket mount	Terminal socket mount	TM relay	TMP type

FIGURE 4.29
Means of mounting of modern relays.

PC board through hole terminal	PC board self-clinching terminal	PC board surface-mount terminal	Plug-in terminal	Quick connect terminal	Screw terminal

FIGURE 4.30
Types of outlets of modern relays.

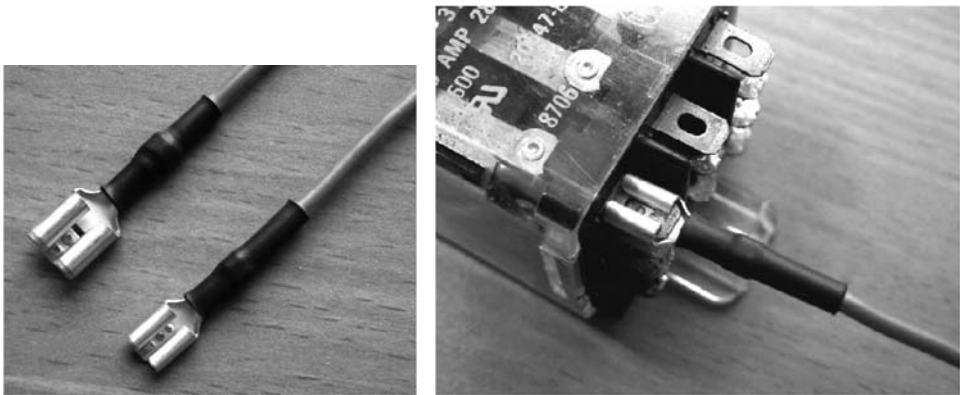


FIGURE 4.31
Faston-type connectors and their use for relay connection

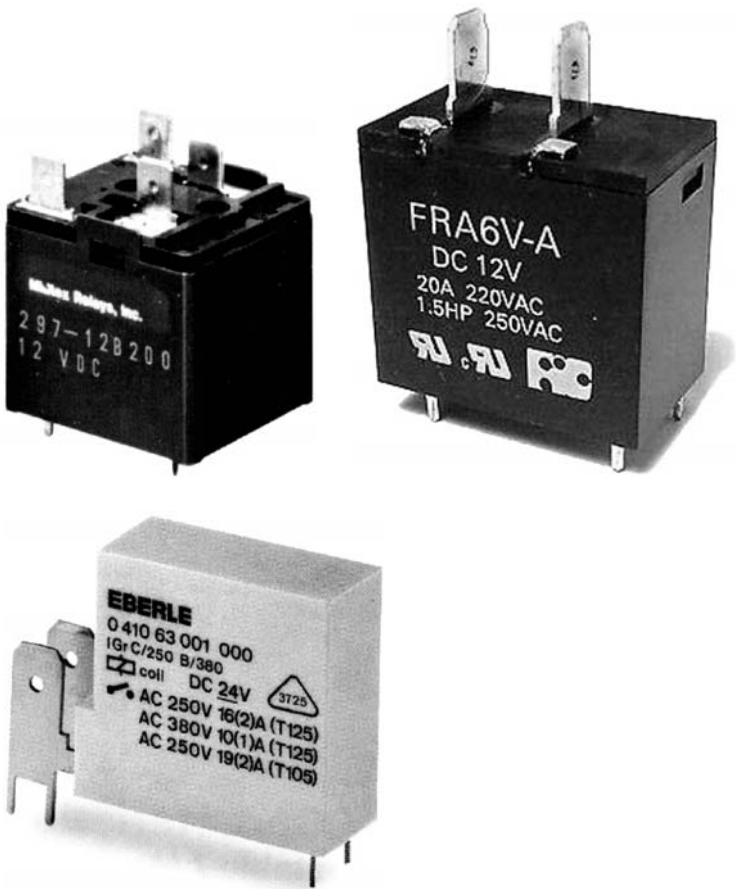


FIGURE 4.32
Relays with hybrid outlets.

**FIGURE 4.33**

Power relay for switching of high currents with screw clamps for external mountings.

4.5 Indicators of Operation and Test Buttons

Apart from the described peculiarities of constructions of cases and relay outlets, recently additional elements have been placed in cases of industrial relays, making their exploitation more convenient. These include, first of all, light-emitting elements displaying the “on” state of the relay (either miniature baseless neon lamps or light-emitting diodes [LED] are usually used as light-emitting elements). These elements are connected through current-limiting resistance parallel to the winding of the relay (LEDs are sometimes connected in series), usually placed under a transparent case of the relay.

RS-series modules (Figure 4.35a) are compact, space-saving relay terminal modules containing six so-called “card relays” — small flat relays with one normally open contact each. All relays contain built-in coil surge-suppression diodes and operation indicators (LEDs) that simplify circuit design and maintenance. The module is easily-mounted on a 35 mm DIN rail.

The firm Shcrack produces indicator elements with LED in the form of separate modules, which can be attached to a relay by placing it next to the relay into a terminal socket (Figure 4.35b). As similar modules the firm produces additional diodes designed for lowering of switching over-voltages, with a relay controlled by a DC coil.

Another additional element is a so-called test button (Figure 4.36) This, in fact, is the same as a plastic pusher, one end of which sticks out through a hole in the relay case, with the other end touching the armature of the relay. As one presses the pusher with the relay in a deenergized state, the armature moves as if affected by the magnetic field of the coil, and switches the contact. This relay is very convenient for setting up of automation devices and for fault tracing in circuits.

4.6 Relays Which Do Not Look Like Relays At All

Power relays for 16 to 25 A currents are more often supplied with an additional unit of contacts, which can be easily attached to the upper part of a relay with a help of plastic catches (Figure 4.37). In this case a plastic pusher of additional unit of contacts meshes with the pusher of the main relay providing synchronous reliable operation of all contacts. A basic relay of this type usually has room for up to four convertible contact units

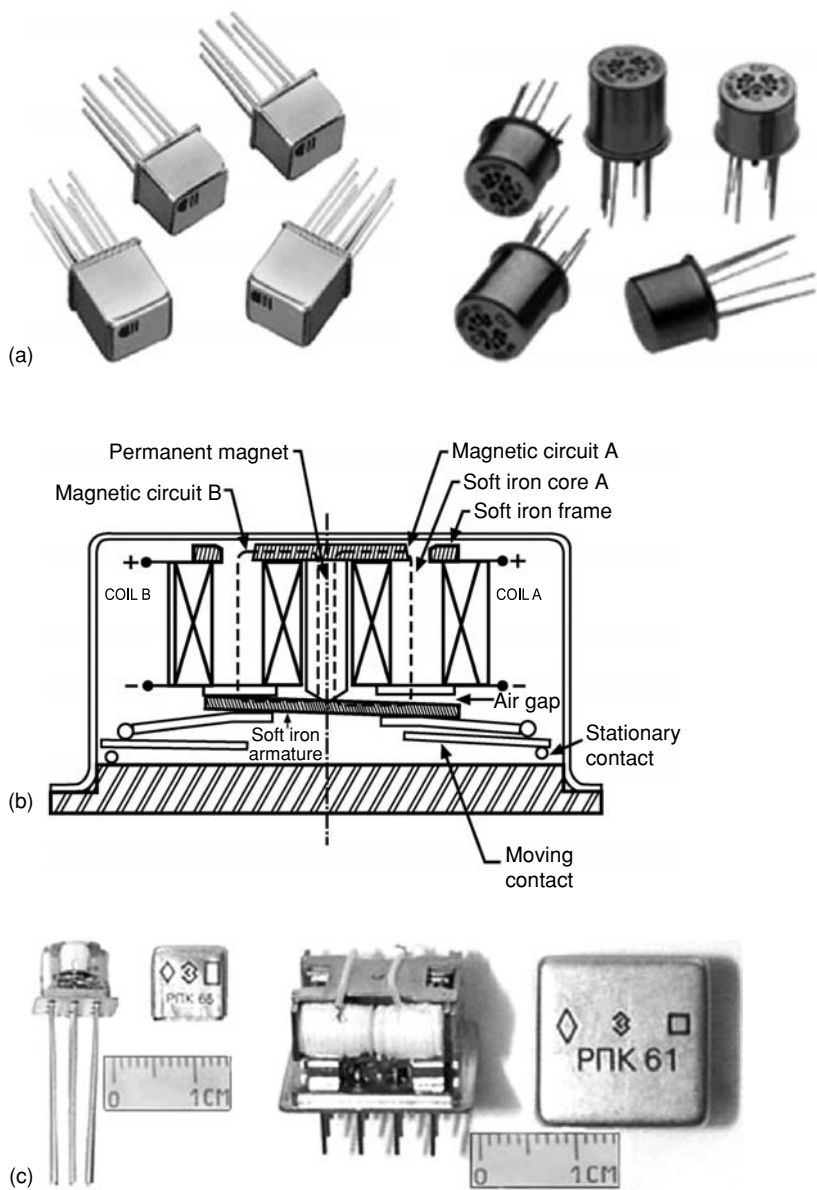


FIGURE 4.34
(a) Micro-miniature relays in standard cases used for transistors and integral circuits (IC), produced by many companies: Teledyne Technologies, CII, Nuova HI-G Italia, Guardian Controls, and others. (b) Construction of micro-miniature relays, produced by Teledyne. (c) External design and construction of new micro-miniature relays, developed by the Russian company "Severnaya Zarya."

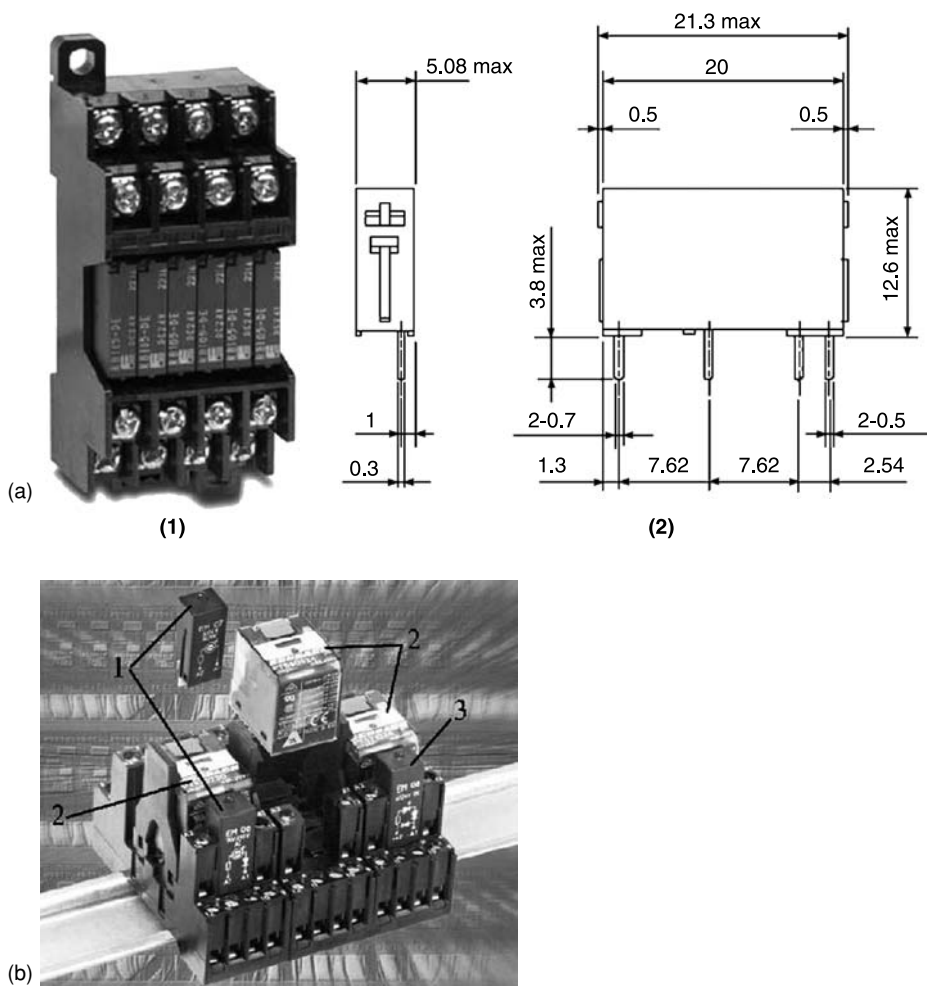


FIGURE 4.35 (a) Module of RS-series card relays and dimensions of separate relay with built-in coil surge-suppression diodes and operation indicators (AutomationDirect Ltd). (b) Modular unit of the firm Shracker. 1 — indicator units with LED; 2 — relay; 3 — unit with diodes.

(cartridges). It can be expanded to 6 or 8 poles by installing an added deck. A 10 or 12 pole relay can be built by adding a second deck.

The American company Olympic Controls Corp. produced a special so-called T-Bar multi-contact relay (Figure 4.38). T-Bar multi-contact relays are designed for use in controlled environments, such as test areas, computer control rooms, broadcast studios and network management centers. The heart of T-Bar components is the 12 pole-switching wafers. Relay assemblies are available in switching configurations of 4, 8, 12, 24, 36, 48 and 60 form “A” contacts (normally open) and 52 form “C” contacts (changeover). The 900 series, designed for dry circuits of a maximum 1 A switching for use in data, thermocouple and instrumentation circuits, and the 800 series, used for control interlock and for indicator circuits.

Many companies produce power relays consisting of a main unit which can be used separately, and a set of many auxiliary units and elements attaching to the main unit

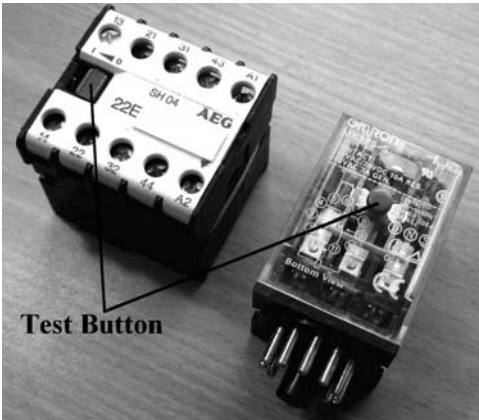


FIGURE 4.36
Relays with test buttons.

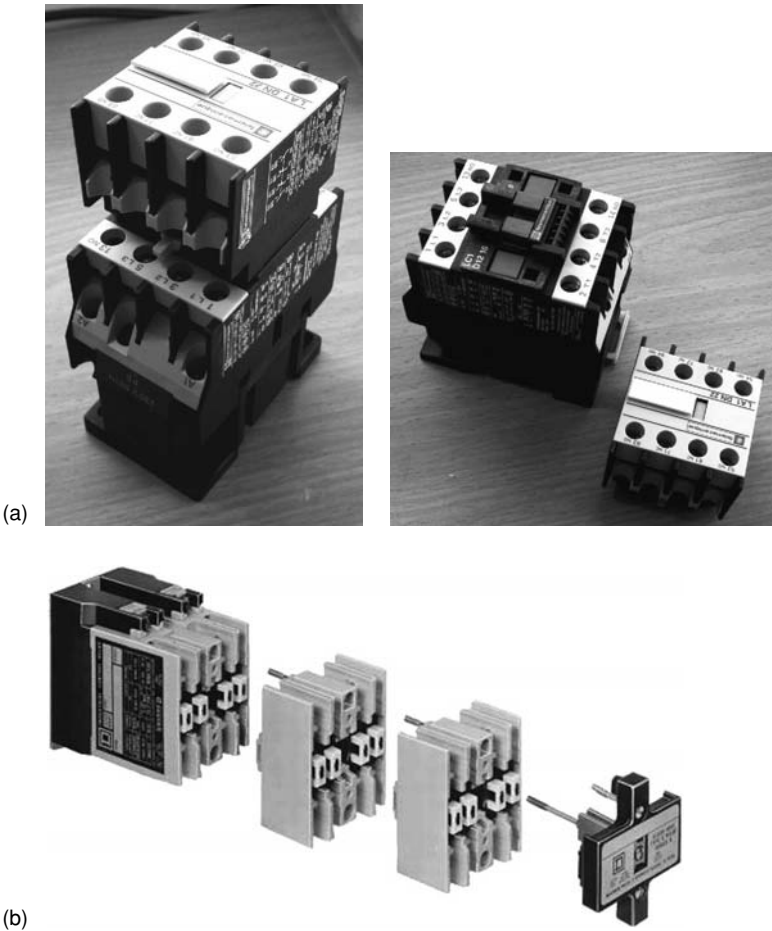


FIGURE 4.37
Power relays modular construction with attached units of additional contacts. (a — Telemechanique; b — Square-D).

**FIGURE 4.38**

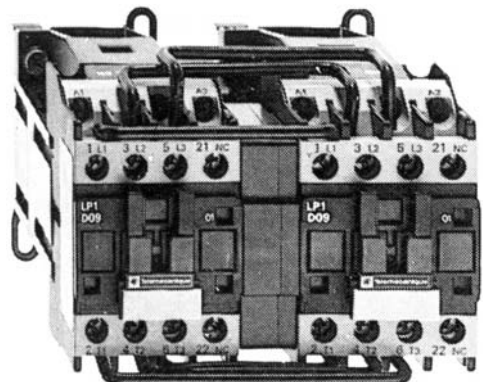
T-Bar type multi-contact relays, produced by Olympic Controls Corp. (U.S.A.). (From Olympic Control Corp., Online Internet Catalogue, 2004)

(indicator unit, diode unit, additional contacts, time delay unit, overload protection unit, and others) on all sides and considerably broadening the capabilities of the device. Such power relays, designed for reversing start-up of electric motors, are often produced as twin-units supplied with mechanical and electronic blocking prevention from the synchronous switching of both relays, and are supplied with all of the necessary bonds (Figure 4.39).

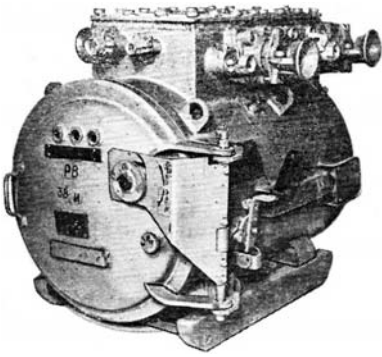
Especially amazing are the so-called explosion-proof electromagnetic contactors and relays. No, these devices have nothing to do with military equipment. They are used in coal mines. All devices of this type are placed in massive steel cases with hermetic hatches, which can withstand explosion both inside and outside of the shell. They look really original (Figure 4.40). This kind of product (Figure 4.41) is suitable for mining wells with their explosive mixed gas and coal dirt, and for direct starts, stops, and turnovers in the three phase squirrel cage different step electrical motor with AC 50 Hz, rated voltage up to 660 V, rated current up to 120 A.

Relays designed for switching of strong signals of high frequency also look quite unusual (Figure 4.42). The major applications of such relays are:

- High power transmitter switching
- Radar pulse forming networks
- Phased array antenna systems

**FIGURE 4.39**

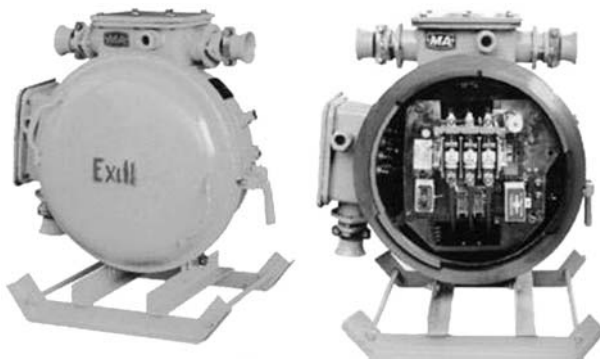
A twin (so-called "reversing") contactor produced by Telemecanique.

**FIGURE 4.40**

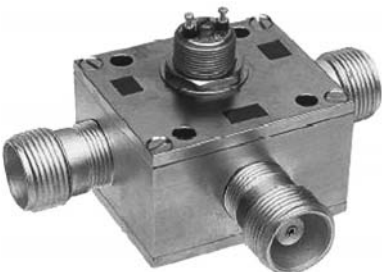
Explosion-proof electromagnetic contactor of PB-1140 type for 250 A current and 1140 V voltage (Russia). Size: 870 × 850 × 980 mm; weight: 410 kg

- UHF/VHF communications systems
- Magnetic resonance imaging systems

Such relays have high power handling capabilities in a small package. The ability to often handle up to 3 to 5 kW (up to 90 kW for some models of Jennings relays, [Figure 4.43](#)) at frequencies of up to 30 MHz is achieved with vacuum-enclosed contacts, minimizing noise and losses. Such rugged switches are capable of “hot” switching kilowatts of 30 MHz with optional special tungsten–molybdenum contacts to avoid pitting when switched with RF power applied. Even with heavy-duty construction, hot-switching will reduce the typical operational life of 1,000,000 cycles significantly — to approximately 10,000 cycles.

**FIGURE 4.41**

120ND series mining explosion-proof vacuum changeover electromagnetic starter for 120 A current and 660 V voltage (Yueqing Bada Vacuum Electric Appliances Switches Factory, China).

**FIGURE 4.42**

Powerful high-frequency relay of 310 series (DowKey Microwave).

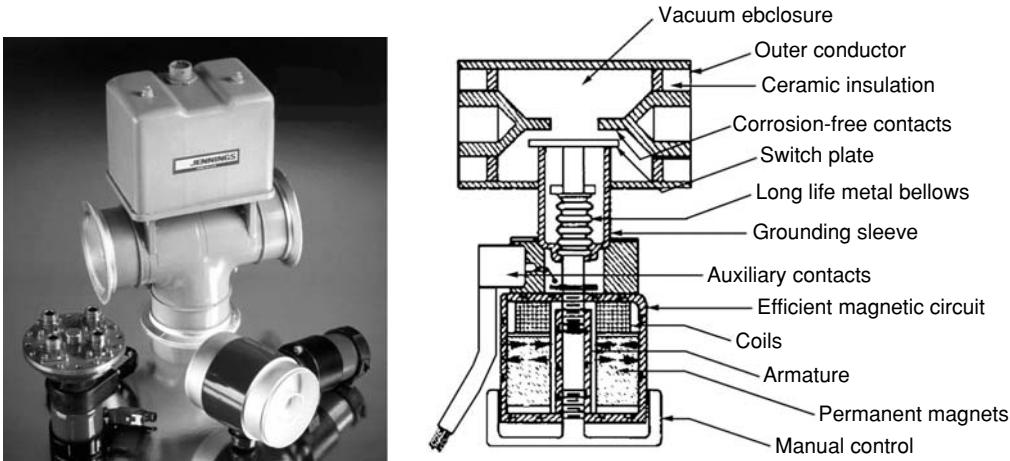


FIGURE 4.43
High Frequency Vacuum Coaxial Relays, produced by Jennings Technology (U.S.A.). (From High Voltage Vacuum and Gas-Filled Relays, Joslyn-Jennings Corp. Catalog. REL-103, 1993.)

TABLE 4.1
Main Parameters of DowKey 310 Series Relay

Frequency (MHz)	VSWR (max)	Isolation dB (min)	Ins. Loss dB (max)	RF Power Watts (CW)
30	1.05	35	0.07	3000
50	1.06	30	0.08	2300
100	1.08	25	0.09	2000
400	1.10	17	0.1	850

Switching capacity of such relays is characterized by a number of specific parameters (“standing wave ratio,” “crosstalk attenuation,” etc.) denoting distortion and waste in the radio-frequency circuit in the closed state, and by a capability to insulate radio-frequency circuits in the open state. We will not go into details of terminology for high and ultrahigh frequencies as this issue lies outside the scope of this book. Here we will give an example of technical specifications for a DowKey 310 Series relay (Table 4.1).